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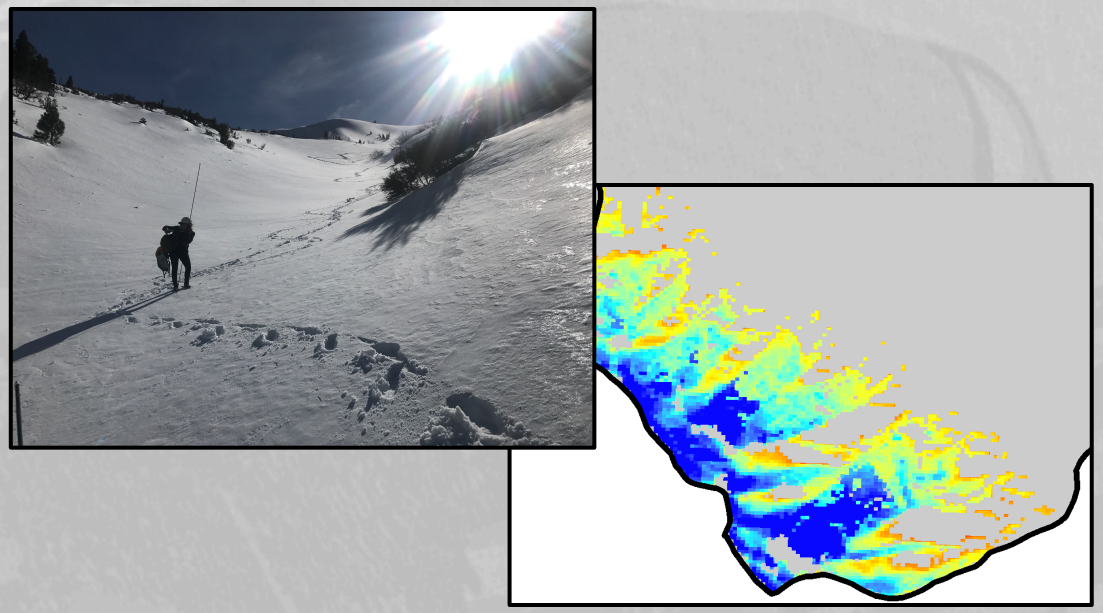
Assessment of Potential Runoff to West Lemmon Valley



April 4, 2017

U.S. Department of the Interior
U.S. Geological Survey

West Lemmon Valley Snow Cover
Overview of Methods

- Model snow depth across the basin using long term remote sensing data and recently acquired snow depth data
- Constrain modeled snow water equivalent to area of snow cover mapped via remote sensing on March 28, 2017
- Convert modeled snow depth to snow water equivalent using recently acquired snow density measurements
- Estimate total volume of water in the snowpack by summing modeled snow water equivalent for all pixels within the watershed

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West Lemmon Valley Snow Cover

Spatial Variability in Snow Depth Across Upper Drainage

- Substantial variation in depth and snow water equivalent over short distances
- Main factors:
  - Variations in incoming solar radiation on different slopes and aspects
  - Wind redistribution of snow cover

Upper Lemmon Creek Drainage, March 27, 2017

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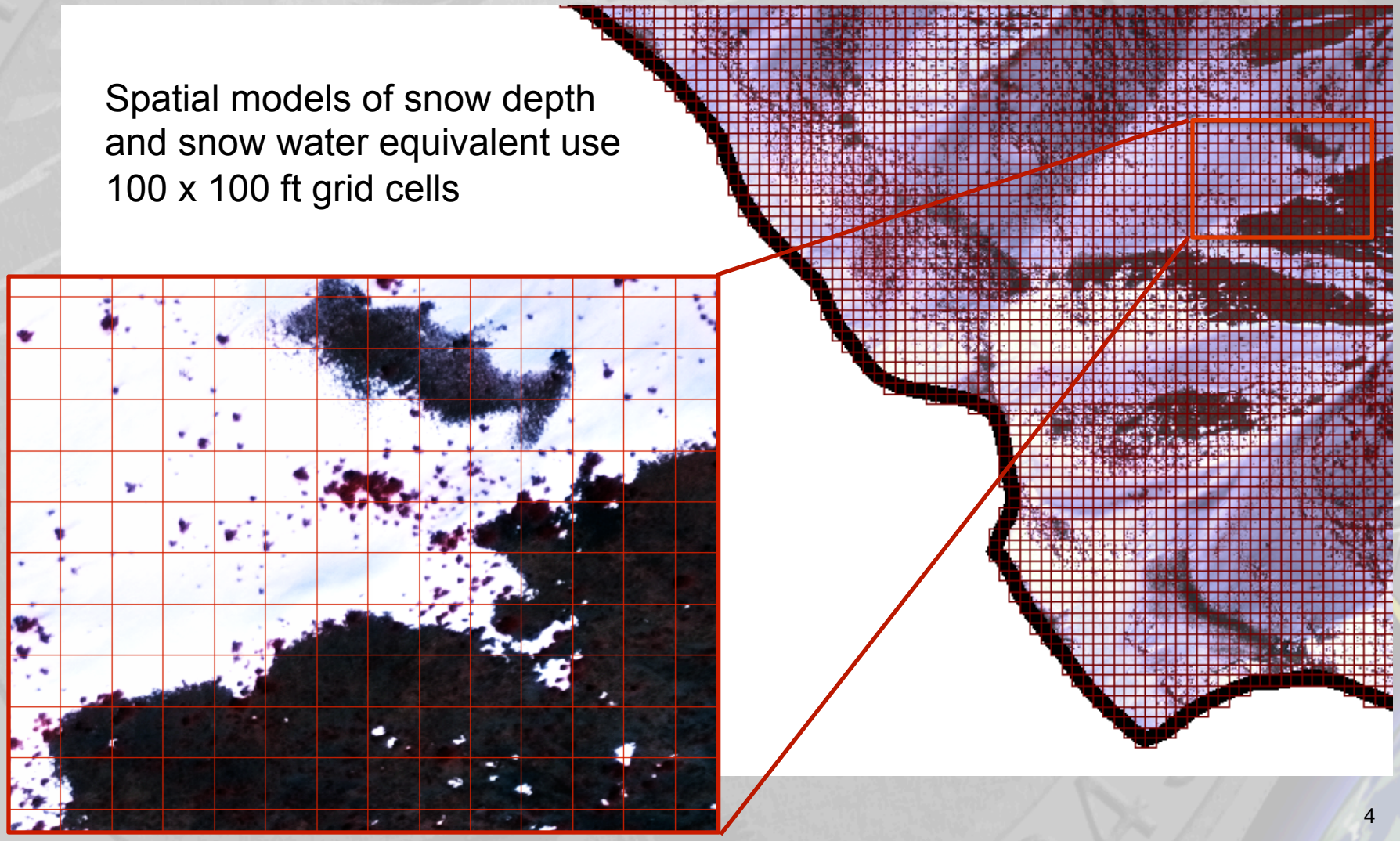
West Lemmon Valley Snow Cover

Modeling: 100 x 100 foot grid cells

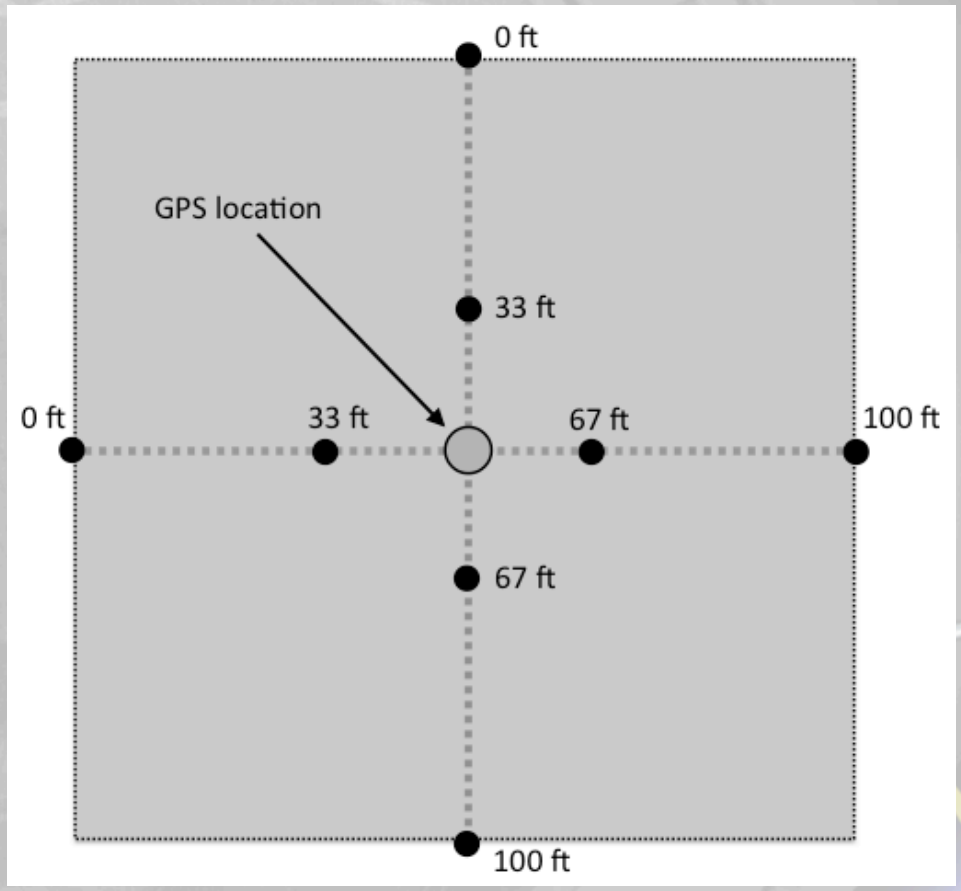
Spatial models of snow depth and snow water equivalent use 100 x 100 ft grid cells



West Lemmon Valley Snow Cover

Field Collected Snow Depth Measurements: Snow Depth Survey Design

- Snow depth measurements at 33 foot increments along north-south and east-west axes (8 depth measurements total)
- GPS location recorded at intersection of two axes
- Designed to represent snow depth within a 100 x 100 foot grid cell



Survey design for a single 100 x 100 ft model Grid cell.

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West Lemmon Valley Snow Cover

Statistical Summary of Field Collected Snow Depth Data

- Substantial variability both between and within grid cells
- Snow depth acquired at 62 grid cells for a total of 496 snow depth measurements
- All 496 snow depth measurements:
  - Max: 200+ inches
  - Min: 0 inches
  - Mean: 68 inches
- Mean grid cell measurements:
  - Max: 175 inches
  - Min: 1 inch
  - Mean: 69 inches

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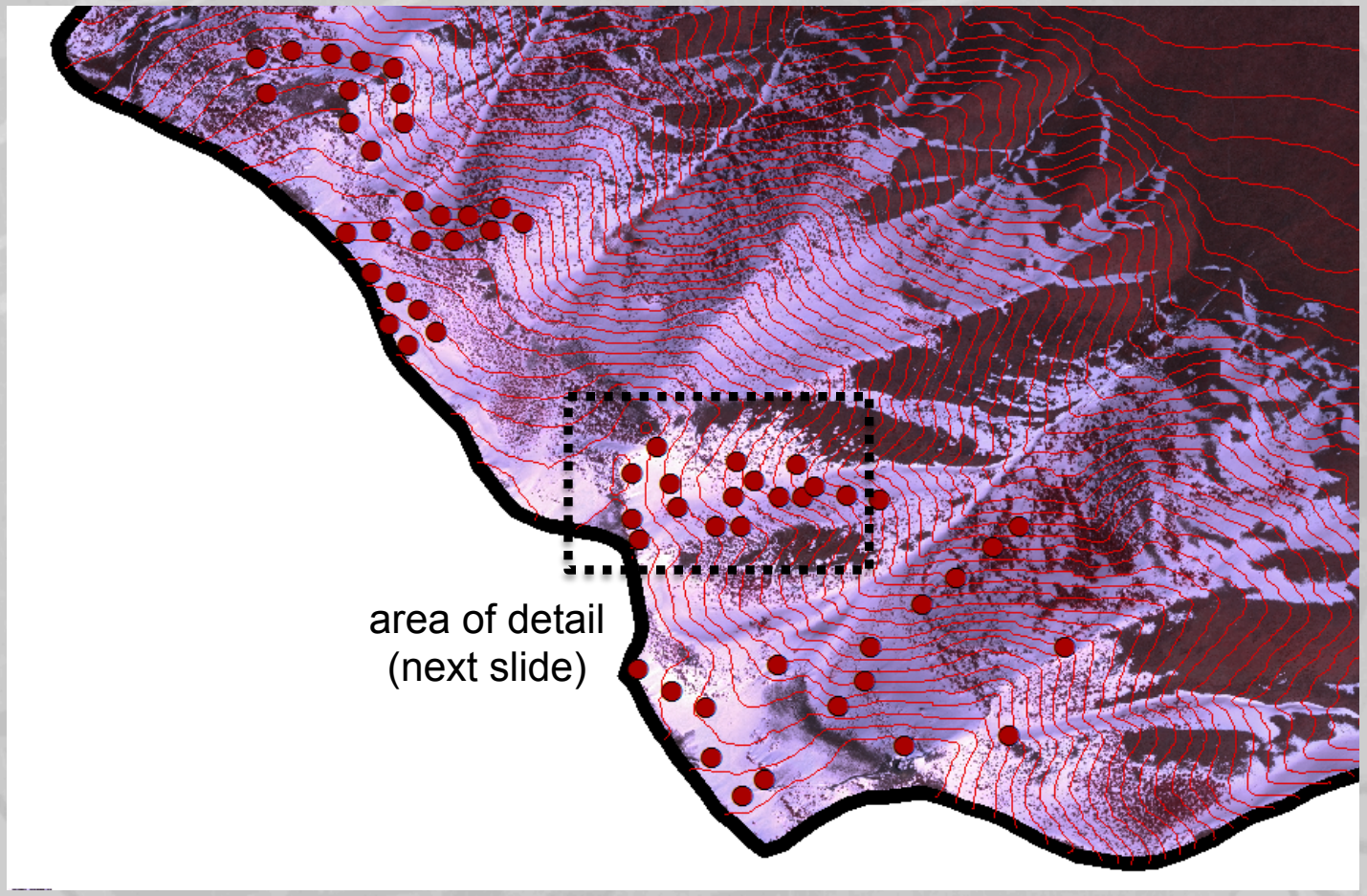
West Lemmon Valley Snow Cover
Field Collected Snow Depth Measurements

Upper Lemmon Creek drainage snow depth survey locations



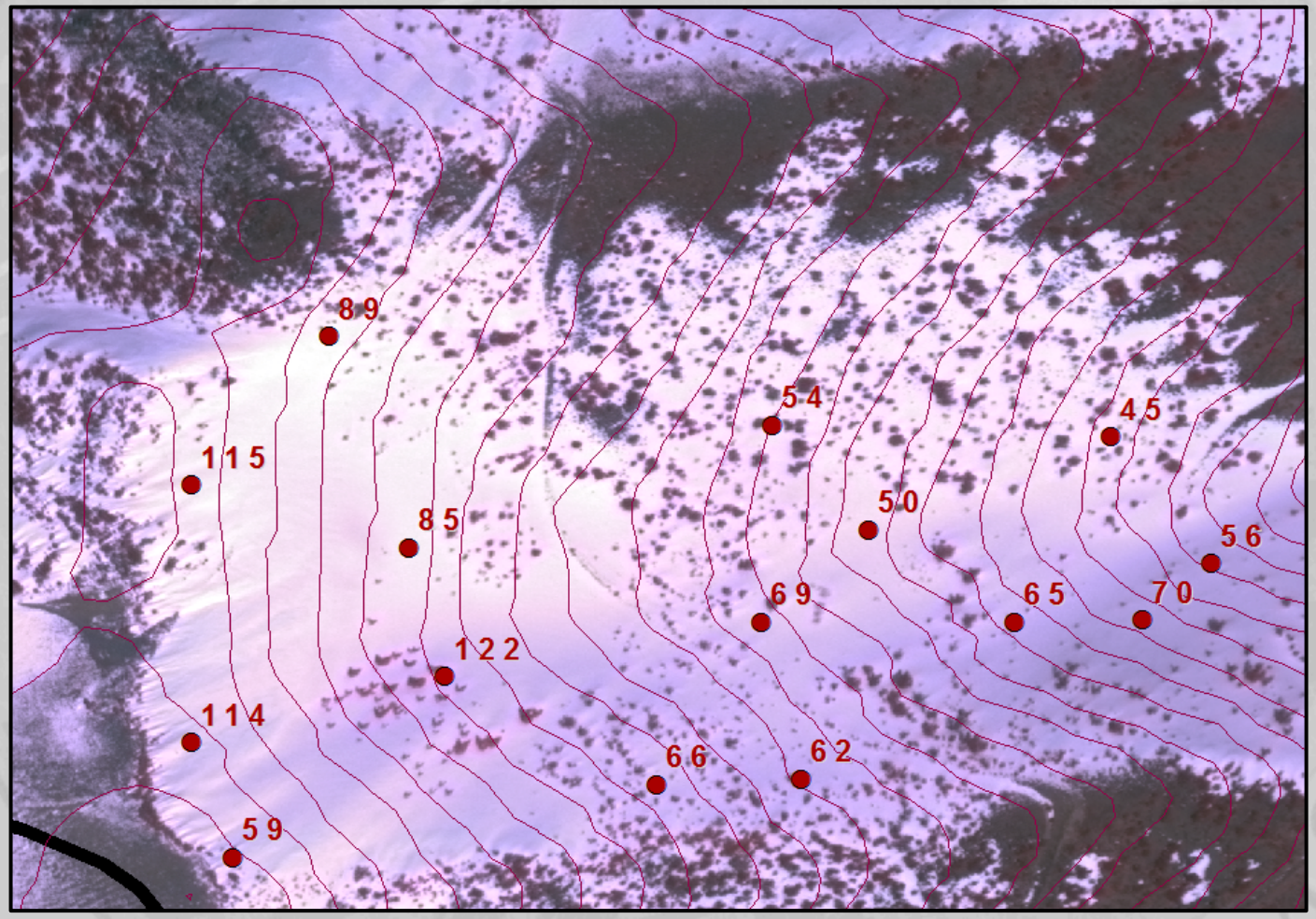
0 1600 ft

snow depth measurement center point

West Lemmon Valley Snow Cover

Field Collected Snow Depth Measurements

Area of detail: mean grid cell snow depth measurements in inches.



0 ft 400 ft

West Lemmon Valley Snow Cover

Field Collected and SNOTEL Snow Density/SWE Measurements

- Snow density: ratio of snow water equivalent to snow depth
- Can be highly variable early season, typically less variable in spring snowpack
- Measurements collected on Peavine Mountain, April 1, 2017:
  - n = 23, mean = 0.445, minimal variability
- Data from nearby SNOTEL stations, April 1, 2017:
  - n = 12, mean = 0.449, minimal variability
- Snowpack approaching maximum density, ripe for runoff

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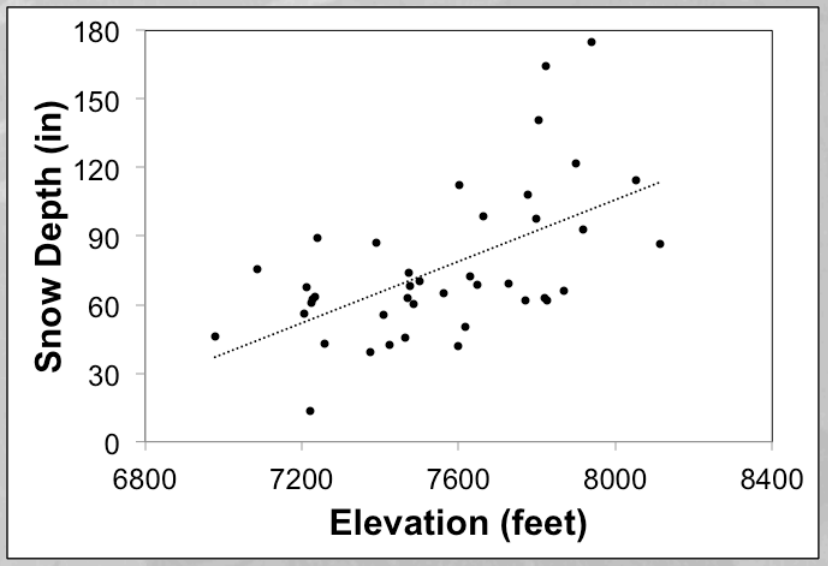
West Lemmon Valley Snow Cover
Snow Depth Models

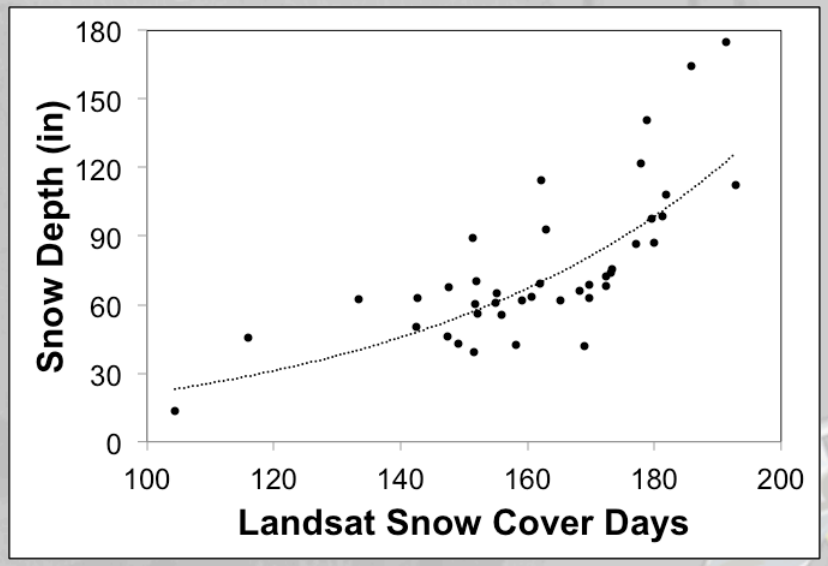
- Landsat-derived mean annual snow cover duration predicts snow depth with higher accuracy than elevation

Elevation



Linear model R^2 = 0.32
Exponential model R^2 = 0.31

Landsat Snow Cover Duration



Linear model R^2: = 0.52
Exponential model R^2 = 0.62

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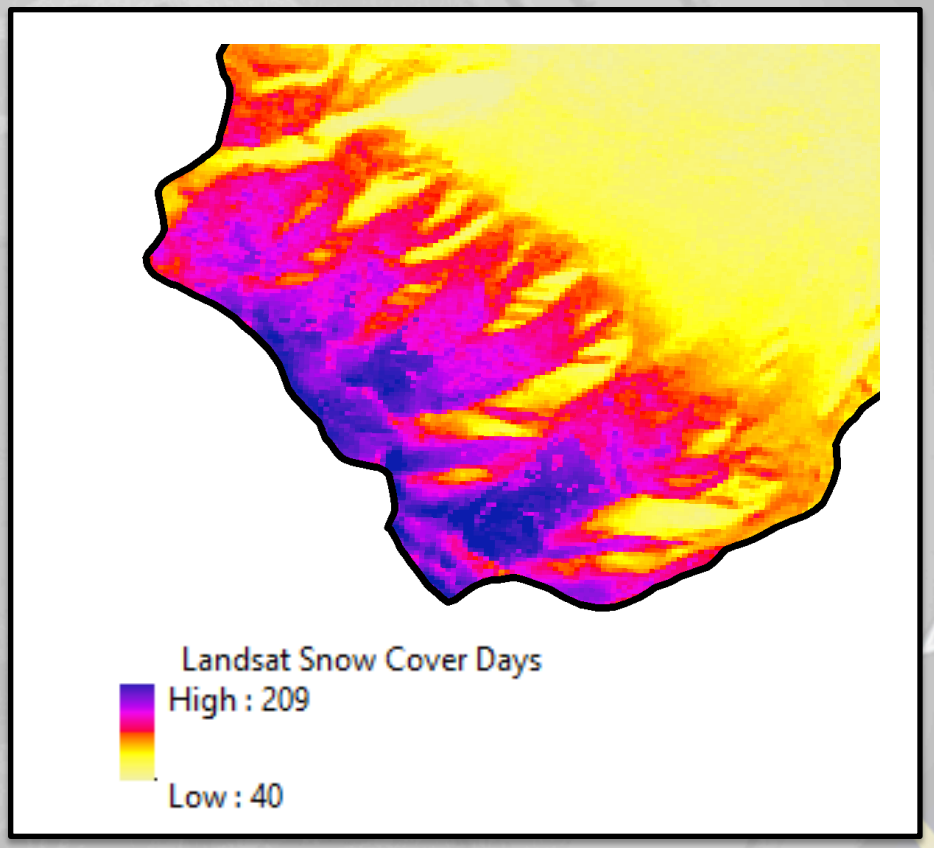
West Lemmon Valley Snow Cover

Landsat-derived Mean Annual Snow Cover Duration

- Average annual snow cover duration typically correlated to spring snow depth and snow water equivalent
- Average annual snow cover duration product available from Landsat satellites



Landsat-derived mean annual snow cover duration (in days), 1984-2015.

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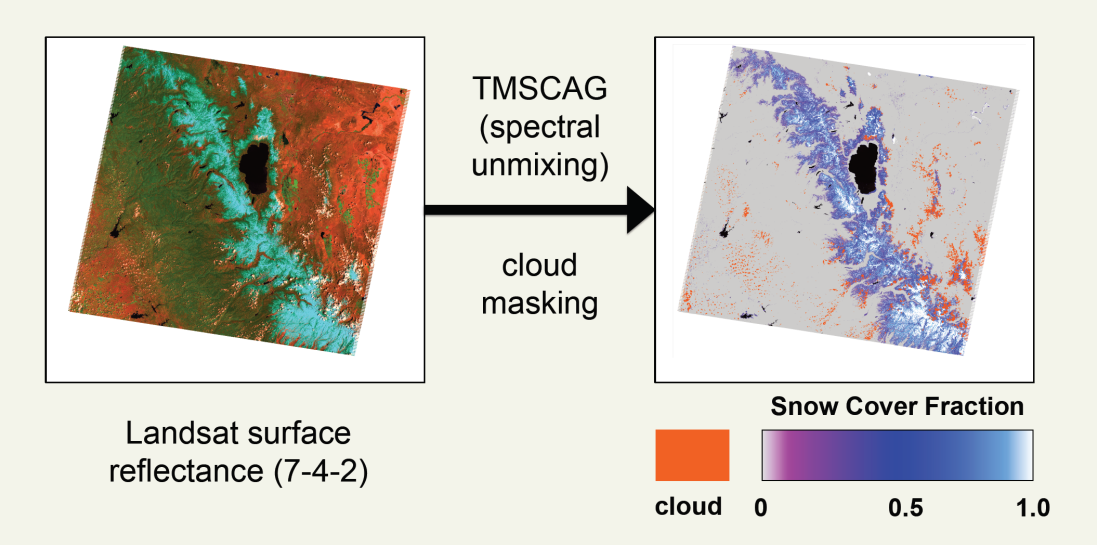
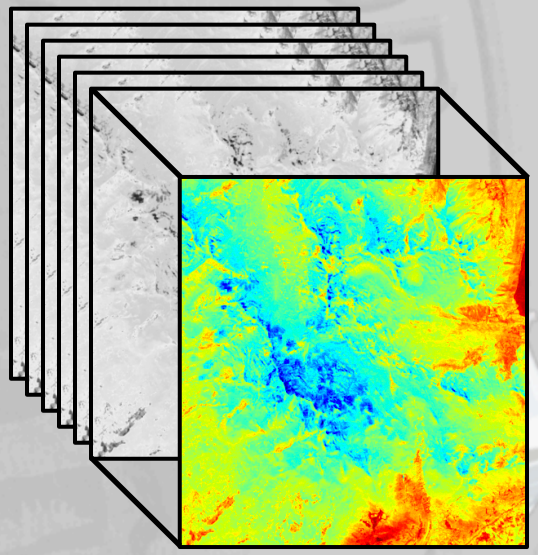
West Lemmon Valley Snow Cover
Landsat Snow Covered Area - Overview

- Landsat measures reflected radiation in different spectral bands to evaluate land surface conditions
- Mean annual snow cover duration calculated for 1984-2015



scene-based fractional snow covered area



snow cover duration

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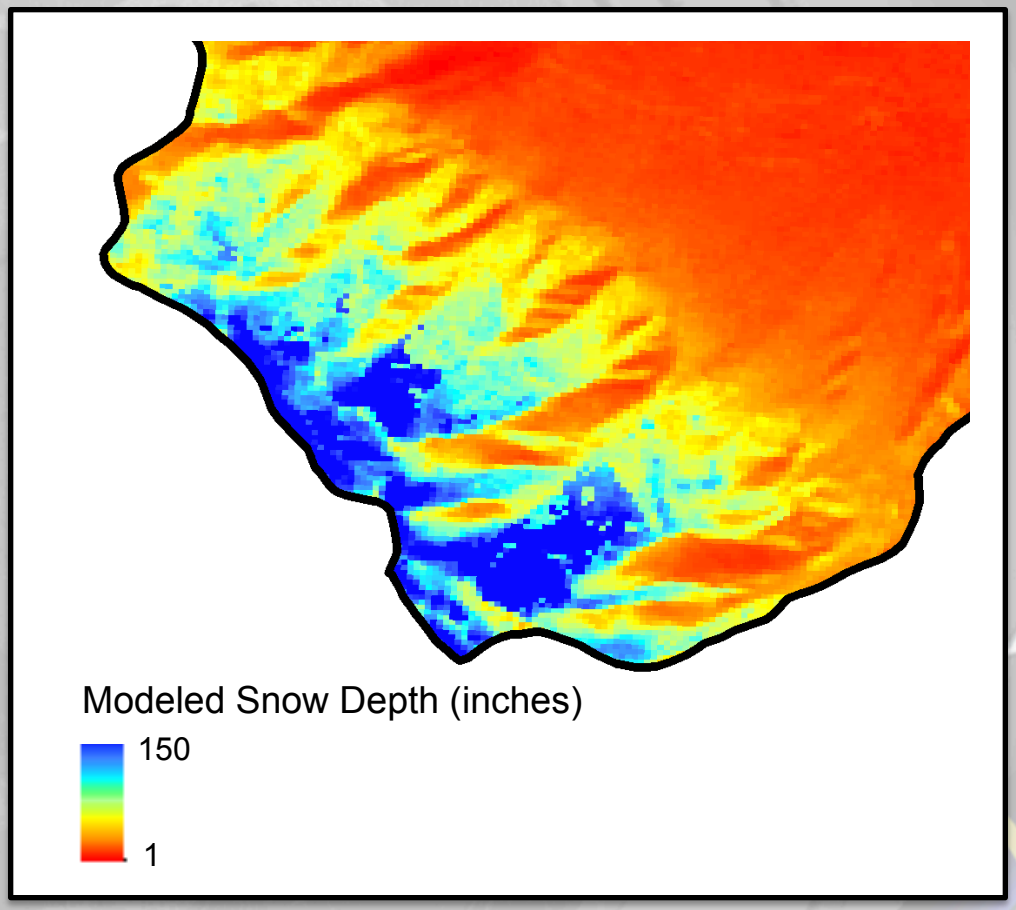
West Lemmon Valley Snow Cover
Landsat Snow Depth Model

- Snow depth estimated across the entire upper watershed using exponential equation
- Minimum snow depth modeled is 1 inch, substantial area incorrectly mapped as snow covered
- How to constrain modeled snow depth to areas of true snow cover?



Unconstrained snow depth model results for Upper Lemmon Creek drainage.

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West Lemmon Valley Snow Cover
Landsat Snow Depth Model

- Use snow covered area mapped from space

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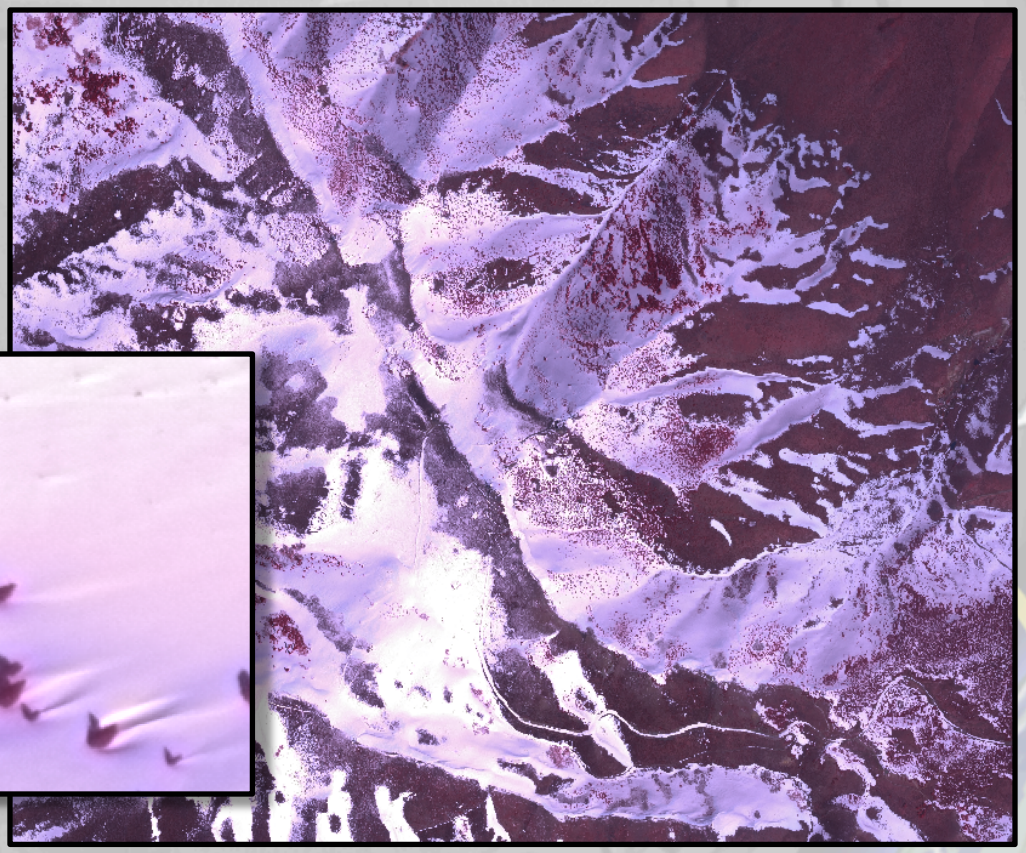
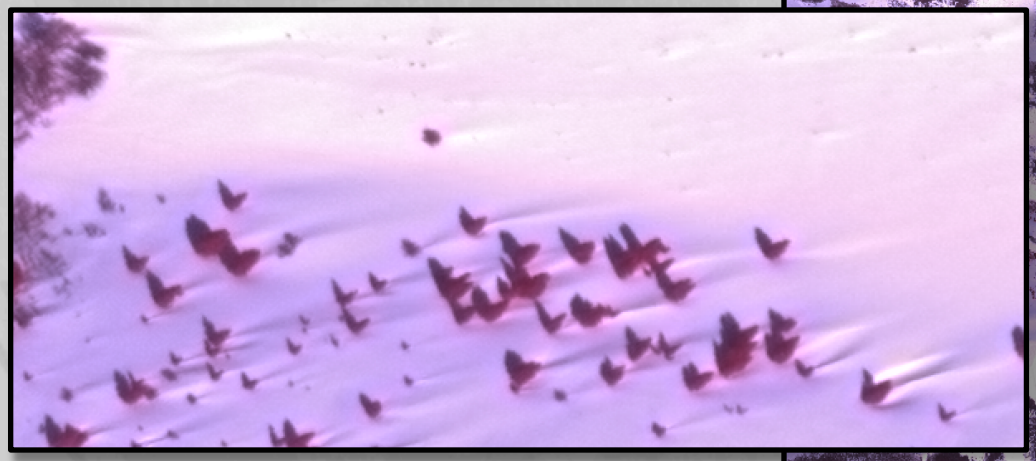
West Lemmon Valley Snow Cover
Remotely Sensed Snow Covered Area

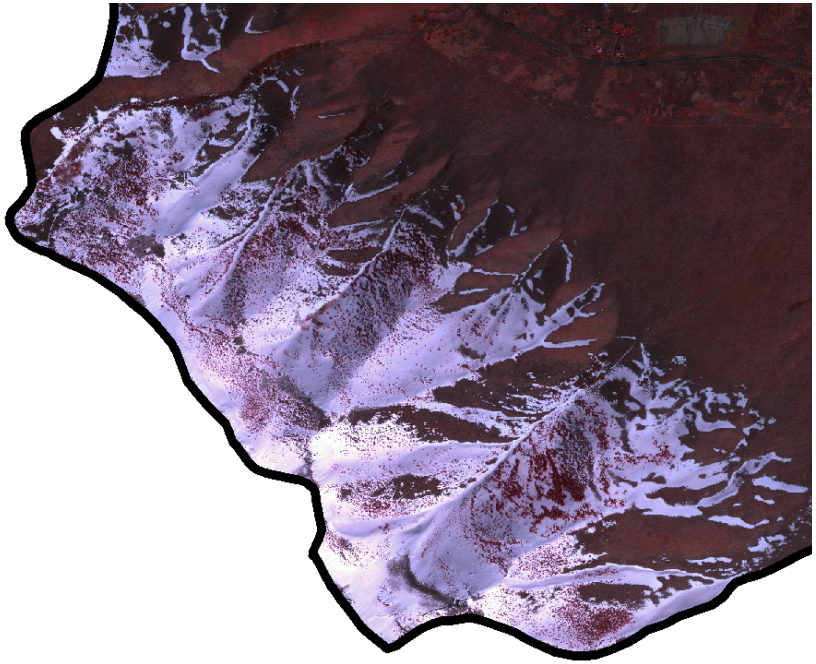
- Request submitted for emergency image acquisition covering Peavine Mountain
- Approved by NGA
- Cloud-free WorldView 2 imagery acquired on March 28, 2017 at 1 foot resolution



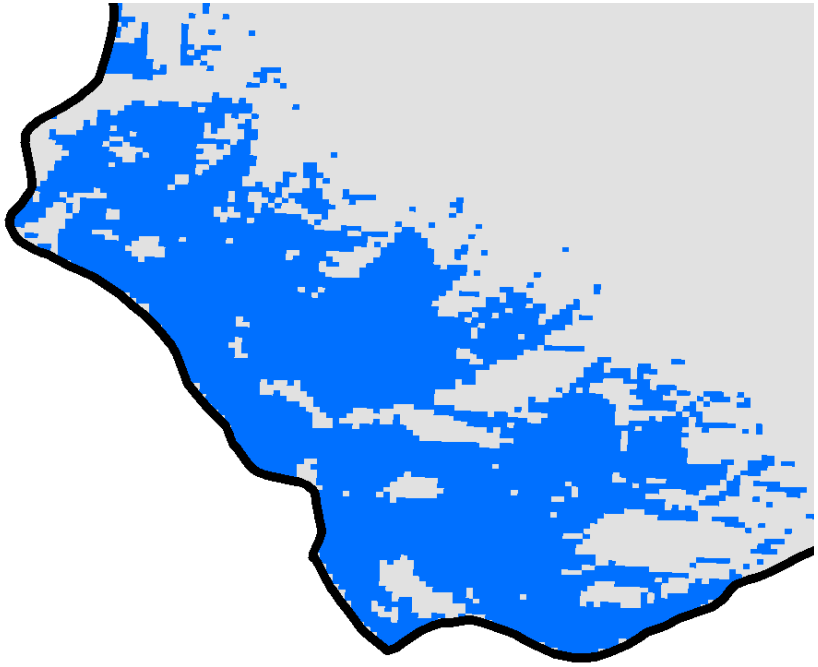


West Lemmon Valley Snow Cover
Remotely Sensed Snow Covered Area

- Combination of automated and manual image processing was used to map snow covered area at 100 foot resolution



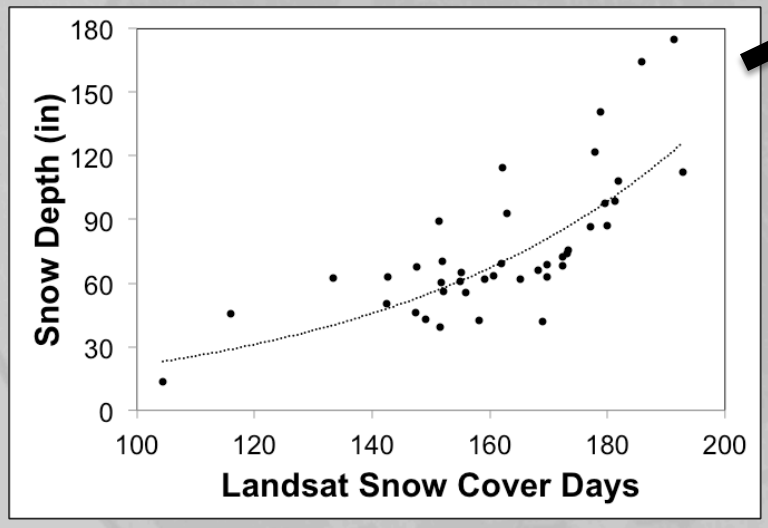
WorldView 2 image (March 28)

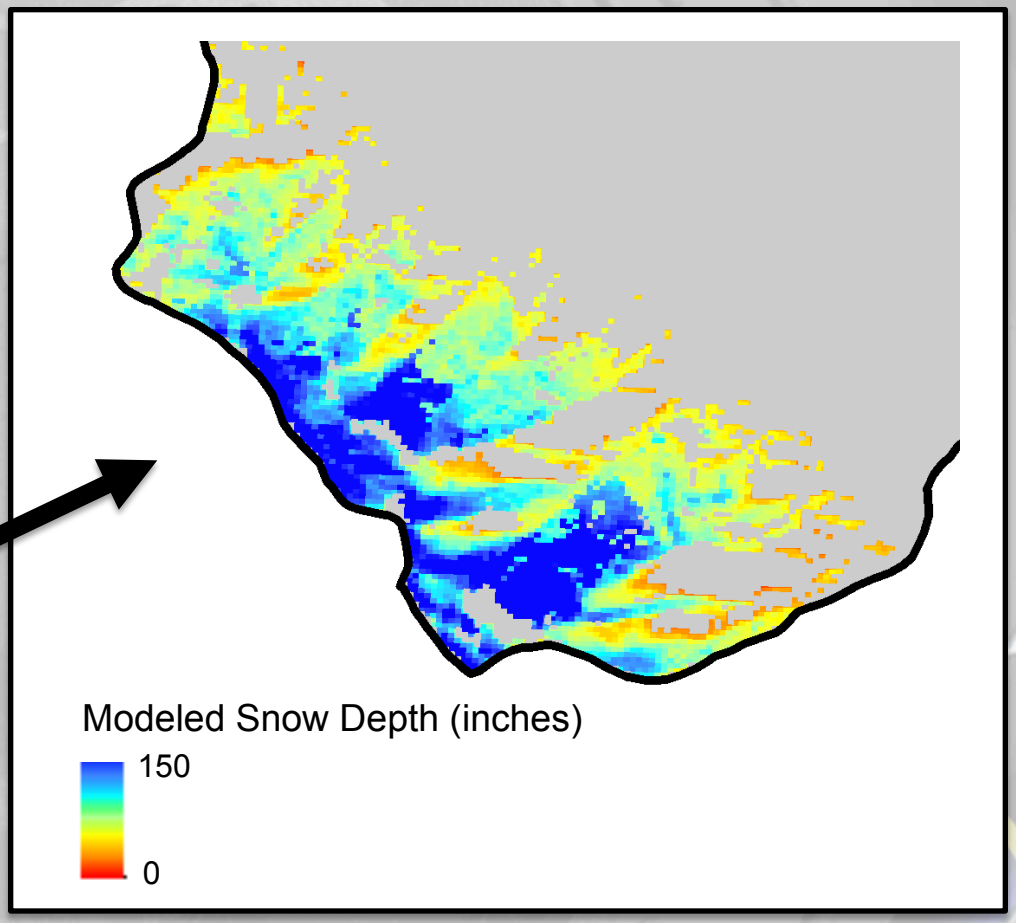


snow covered area (March 28)

West Lemmon Valley Snow Cover
Constrained Snow Depth Model

- Estimated snow depth grid results constrained to area mapped as snow covered March 28, 2017
- Modeled snow depth set to 0 for areas not mapped as snow covered

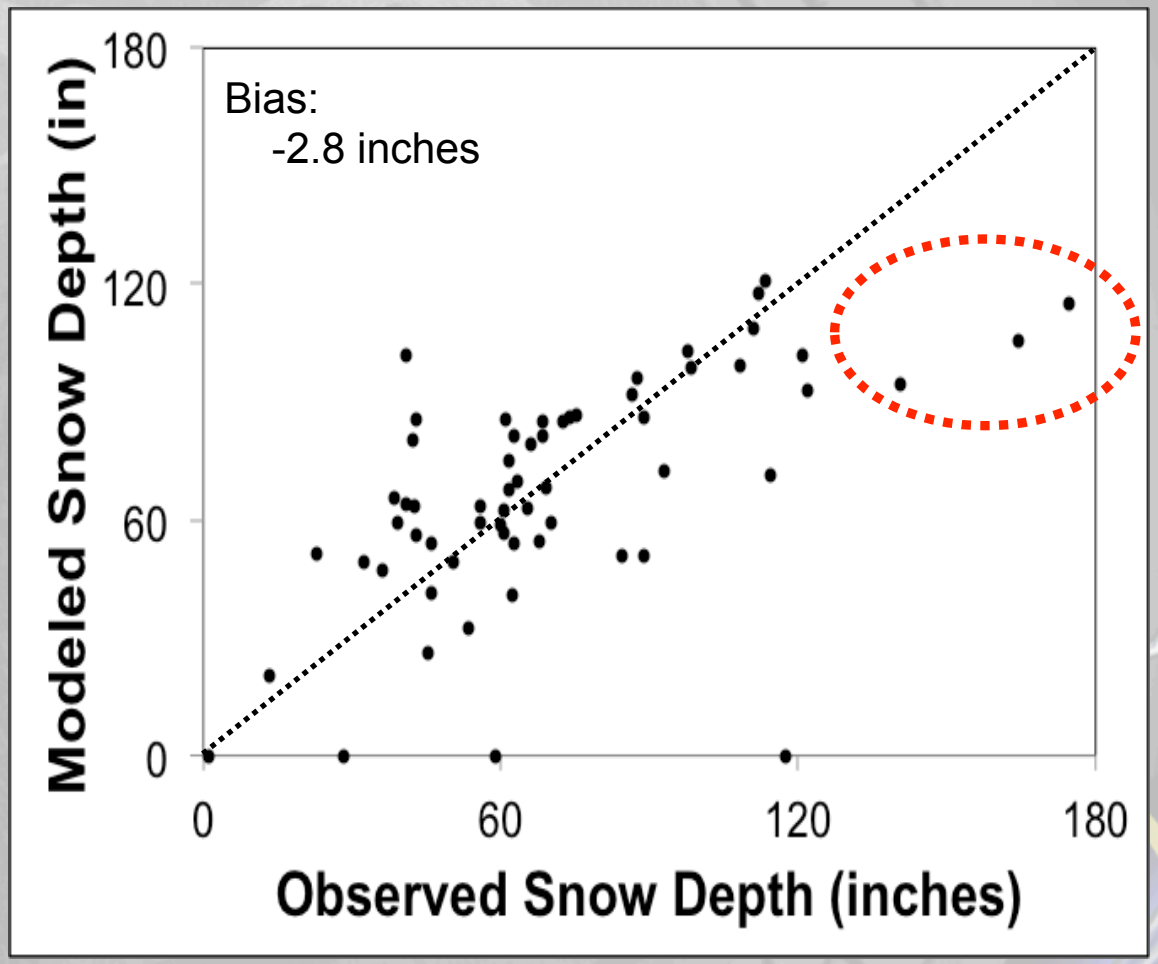




Estimated snow depth for Upper Lemmon Valley drainage, constrained to areas of remotely sensed snow covered area.

West Lemmon Valley Snow Cover
Assessment of Snow Depth Model

- Comparison of estimated snow depths to field observations
- Good fit
- Exceptions:
  - a few points on the border of snow-free pixels,
  - underestimation of deepest snow cover



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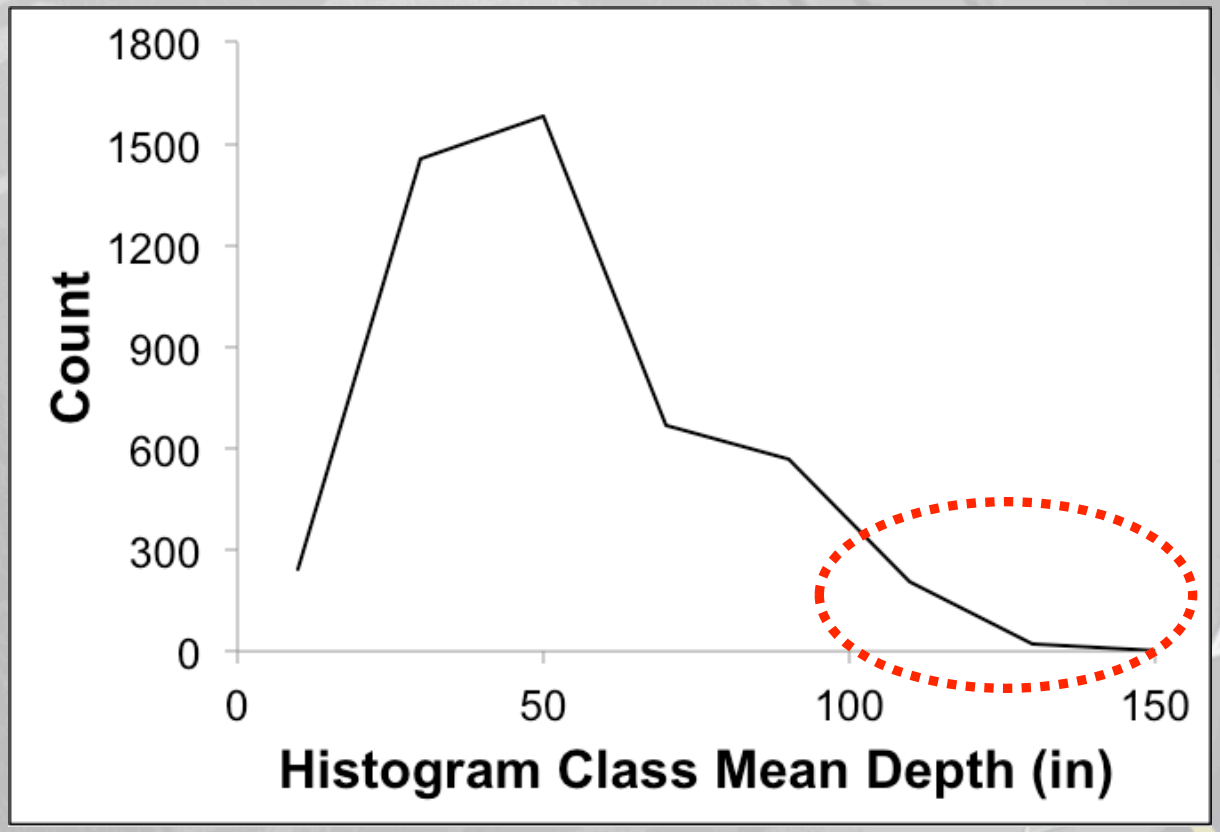
West Lemmon Valley Snow Cover
Assessment of Snow Depth Model

- Underestimation of snow depths > 100 inches
- Only a few grid cells > 100 inches
- Very small impact on total stored SWE estimate



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West Lemmon Valley Snow Cover
Estimation of Snowpack Volume

- Mean snow density value of 0.446 used to calculate snow water equivalent for all pixels
- For all grid cells:
  - Modeled Snow Depth x Density = Modeled Snow Water Equivalent
- To obtain total volume of water in the snowpack
  - 4745 pixels with snow cover; equivalent to 1055 acres
  - Mean snow water equivalent (snow covered pixels only): 23.3 inches or 1.9 feet of snow water equivalent
  - 1.9 feet x 1055 acres = 2100 acre feet of potential runoff

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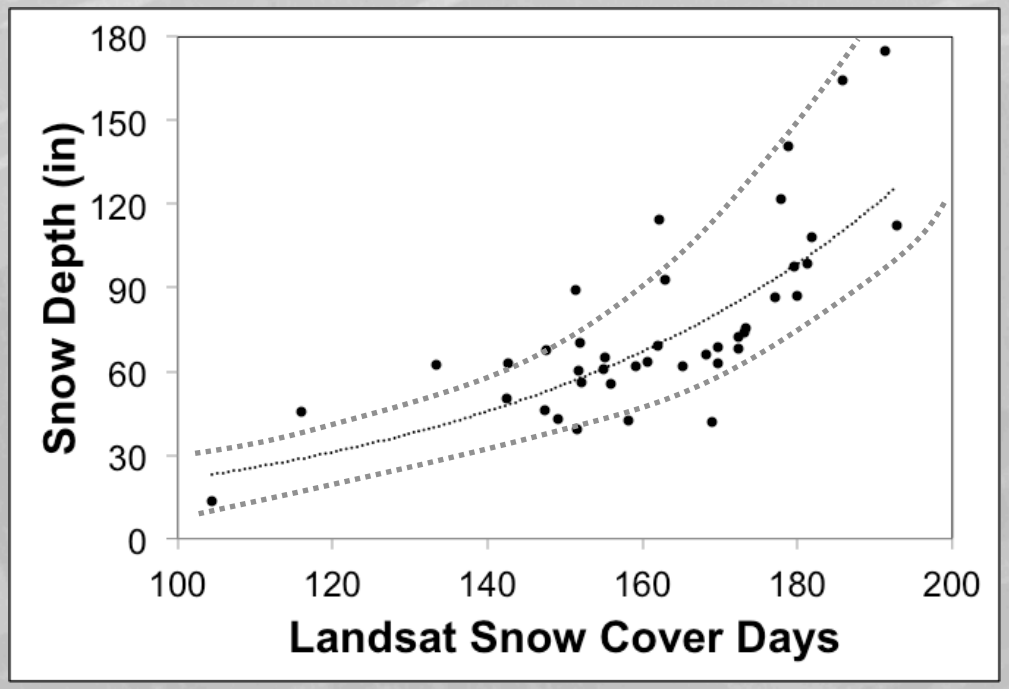
West Lemmon Valley Snow Cover
Potential Uncertainty

- Range of stored snow water equivalent based on uncertainty in both depth and density:



snow density range

0.425

0.445

0.475

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West Lemmon Valley Snow Cover
Potential Uncertainty

- Using the model parameters shown in the previous slide, stored snow water equivalent in Upper Lemmon Valley is most likely in this range:
    - 1,700 acre feet (low end, similar to previous DRI estimate)
    - 2,100 acre feet (best estimate)
    - 2,800 acre feet (upper end, less likely but possible)

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West Lemmon Valley Snow Cover
Snowpack Volume

- Why are these estimates higher than previous DRI/NOAA estimates?
  - Earlier survey in East Lemmon Valley drainage found only 5% of measurements exceeded 120 inches
  - in East Lemmon Valley no measurements > 120 inches collected due to equipment limitation
  - West Lemmon Creek (this survey) found
    - > 10% of measurements exceeded 120 inches in depth
    - 3% of measurements exceeded 160 inches
    - 1% of measurements exceeded 200 inches

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West Lemmon Valley Snow Cover
Potential Lake Rise

- Based on March 22, 2017 DRI estimate of 700 flooded acres for Silver Lake:
  - 1,700 acre feet could lead to a 2.4 foot rise
  - 2,100 acre feet could lead to a 3 foot rise
  - 2,800 acre feet could lead to a 4 foot rise
- Unknown lake geometry: as lake expands in area, each additional 700 acre feet of stored water may no longer correspond to a 1 foot rise in lake level

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West Lemmon Valley Snow Cover
Additional Unknowns

- Rate of snowmelt:
  - Rapid rise in temperatures and clear skies, or heavy warm rain could result in quick delivery of the majority of snowpack water volume
  - Gradual warming or cloudy conditions would result in a slower delivery of snowmelt runoff
- Absorption of snowmelt runoff by the soils will be minimal this year as soils are saturated
- Evaporation from the lake: around 3 inches in April, around 5 inches in May

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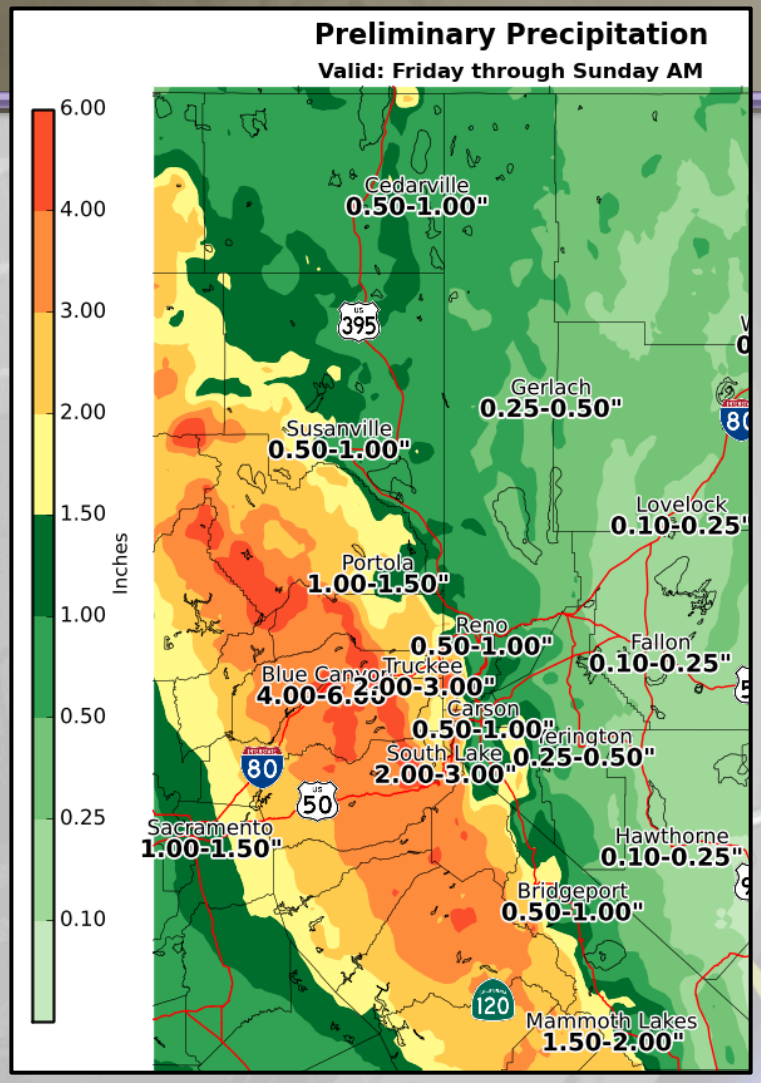
West Lemmon Valley Snow Cover
Additional Unknowns Continued

- Additional precipitation expected later this week:
  - Another atmospheric river event on the horizon
  - 1-2 inches of liquid precip for the upper elevations
  - Potentially a warm event, could come as rain
  - 2 inches of rain onto existing snow covered area would add nearly 200 acre feet, runoff very quickly



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West Lemmon Valley Snow Cover
Additional Unknowns Continued

- Small patches of snow remaining in the northern hills, not estimated here
- Could possibly add a few hundred additional acre feet

USGS

West Lemmon Valley Snow Cover
Questions and Contact Information

- Questions?

Presentation available at:

https://nevada.usgs.gov/water/Flood2017/lemmonvalley.html

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